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James Watt: The steam engine and the commercialization of patents

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Abstract

Great Britain (GB) was the first country to undergo an Industrial Revolution (1760–1850) and, in consequence, the first where patents for inventions evolved from an occasional curiosity to a powerful commercial tool. It is argued that this paradigm shift was largely caused by the later development of the steam engine and especially the first patent of James Watt (1736–1819). Despite extensive litigation, this proved extremely lucrative and thereby convinced GB's rapidly growing industry of the importance of strong patent protection.

In an annex, the author notes that 2008 is the 200th anniversary of the demonstration of the first practical steam railway engine, Richard Trevithick's 'Catch me who can' on a circular track in London.
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1. Pre-industrial revolution

Before 1750 most countries had pockets of manufacture and mining but they were minority pursuits in what were largely agricultural societies. GB[1] was typical in that at least 80% of the population lived in rural areas and earned their living mainly through agriculture or rural occupations closely connected thereto. Nevertheless there were localized coal deposits, which could be easily mined without knowledge of geology or sophisticated mining techniques, and these had long been used for heating given the cold wet climate and the absence of cheap timber for fuel. Some was also used for industrial processes, though those that were mechanized still largely used water power. It was estimated that GB produced five times as much coal as the rest of the world in 1650 and this increased rapidly to about 3 million tons a year by 1700. However, GB coal and other mineral production was severely hampered by flooding and the lack of adequate pumps.

2. Early patents

In such a society, where the rate of technical innovation was very slow, patents for invention were quite a rarity. The first English patent, for coloured window glass, was in 1449 – the second one (also for glass making) in 1552! Thereafter there was some speeding up and the total was about 100 by 1617. Given the mining problems it is unsurprising that, of the 182 patents granted in England from 1561–1642, one in seven was for raising of water. The first concerned with mining was by David Ramseye in 1630:

> "To raise water from lowe pitts by fire" and "*To rayse water from lowe places and mynds, and coale pitts by a new waie never yet in use*"

However, since it was also combined with other inventions (including making saltpeter, tapestry making, softening hard iron and making yellow wax white) and no specification was filed, it appears to have been a hope rather than a practical proposition. Another cause of

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[1] GB included England, Scotland and Wales, whose industrialization proceeded in parallel, and Ireland which lagged behind, mainly due to a lack of coal. Before 1852 separate patents had to be filed for England (including Wales), Scotland and Ireland.

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the low numbers were the complex and expensive patent procedures which had been largely designed to prevent monopolies being granted by grasping officials for necessities such as salt and vinegar rather than for positively encouraging technical innovation. Furthermore, apart from duplication for England, Scotland and Ireland, there was no technical examination. Originally the patentee had to actually work the invention though, after 1700 they were increasingly required to file a specification without any agreement as to what technical disclosure it should include; in any case it was filed after grant of the patent. Thereafter any enforcement through the courts was both uncertain and expensive, especially given the minimal policing then available, e.g. collecting royalties from a mine owner backed up by hundreds of miners defending their livelihoods was not a task for the faint hearted! Hence the number of patents granted was very small, e.g. in the 1750s the annual average was only nine. Then as now lucrative patents were only a small minority of the total so, before the late 1700s, patents were widely regarded as an expensive oddity rather than an essential feature of commercial strategy. For example, Samuel Crompton (1753–1827) invented the spinning mule in 1779 which eventually led to a vast increase in the productivity of the textile industry. He never filed a patent, instead relying on voluntary contributions from the textile manufacturers enriched by his invention. His optimistic view of human nature raised the paltry sum of £60 (about £6000 at 2007 prices) though Parliament voted him £5000 in 1812 in recognition of his unique contribution. Nevertheless he died in poverty and suffered the indignity of burial in an unmarked grave. Richard Arkwright (1732–92) secured patents for vital improvements in textile spinning but, after much litigation, his last patent was declared invalid in 1785 thus encouraging the view that patents were ultimately useless [1]. However, he died a wealthy man.

3. The first industrial revolution

This not only involved vastly increased production of coal, iron etc. but accelerating mechanization of production, especially through steam which powered textiles and other industrial processes and eventually drove ships and railways in the early nineteenth century. Despite a doubling of population between 1715 and 1815 it has been estimated that gross national product trebled. Even the Napoleonic Wars from 1793–1815 barely checked this rapid growth whose resulting economic strength greatly contributed to eventual victory. By 1850 at least half the greatly increased population lived in urban areas and GB was justifiably called the "workshop of the world". Historians are still not agreed why this happened in GB though generally date its start to the 1760–70 period when it was noticeable that an entirely new phenomenon was occurring in certain areas. However, its roots clearly went much further back.

4. Steam engines

These can be traced back to Hero of Alexandria in Egypt around 150BC but the first workable coal powered steam pump was made by Thomas Savery (1650–1715) in 1698. It was known as "the miner's friend"- ironically perhaps as it involved starting a fire underground, a dangerous tactic given the high incidence of methane gas explosions! Also it could only raise water by 9–10 m so was of little practical interest. However, he filed a patent so broadly worded that it appeared to cover any use of steam to raise water. A superior and massive surface mounted steam engine pump was designed by Thomas Newcomen (1663–1729) and first installed in a coal mine in 1712. It had a large pumping capacity and could reliably raise water over 50 m so was of immense benefit to the mining industry (see Fig. 1).

Savery and Newcomen apparently agreed patent matters between them thus avoiding litigation but the patent lasted 35 profitable years. However, the big drawback of the Newcomen engine was its low efficiency, hardly surprising giving the total lack of thermodynamic expertise available to these early engineers. This was tolerable in coal mines where the fuel was cheap but was a grave handicap to the English tin/copper mining industry in Cornwall which was far from any coalfield. Newcomen engines were largely constructed on site by local blacksmiths/engineers and thus could vary considerably in efficiency. John Smeaton (1724–92) later used practical engineering techniques to improve these engines by systematic parameter variation. Although there were about 300 operating in UK mines by 1780 this inefficiency, together with its bulk, precluded serious application to any other function e.g. transport.

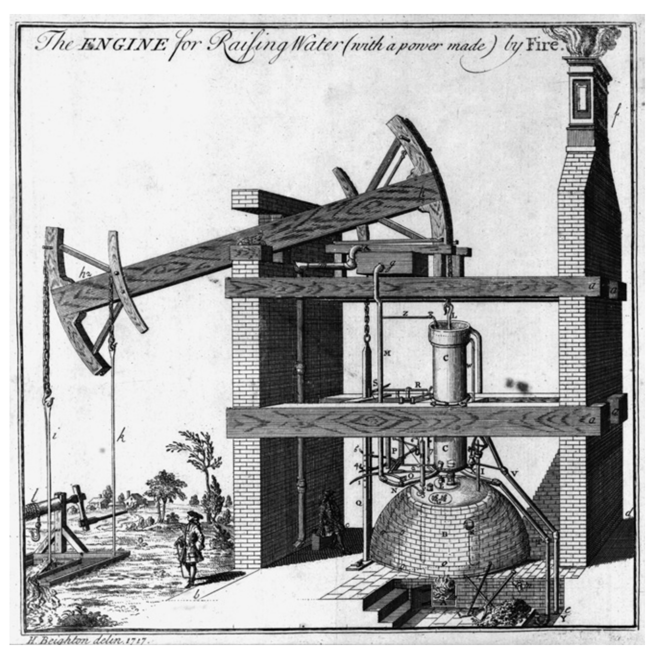

Fig. 1. Newcomen engine.

5. Watt's steam engine

The big breakthrough was achieved by James Watt (1736–1819) who had worked on a model Newcomen engine at Glasgow University in Scotland. (see Fig. 2).

He greatly improved its efficiency by providing a separate condenser and this impressed John Roebuck (1718–1794), a successful industrial chemist who had also founded an ironworks in Scotland. He provided the financial backing for Watt to get his first patent granted in 1769. Watt then had 4 months to file a specification. The usual procedure was to file a detailed description and drawings of a particular engine but Watt took the advice of Dr. William Small (1734–75) and drafted his specification to cover the general principles of his invention only to thereby catch potential infringers. Development work was delayed by Roebuck's bankruptcy in 1773 and, after seven years negotiation, in 1775 Watt formed a partnership with Matthew Boulton (1728–1809), a most fortuitous choice as Boulton was a shrewd businessman and owner of the Soho works in Birmingham, England, a world famous engineering factory. Through this connection Watt joined the Lunar Society in Birmingham, one of GBs leading scientific groups at that time (see Fig. 3).

By then the patent had already run for 6 of its 14 year term so Boulton paid for a private Bill through Parliament in 1775 which extended the patent term for 25 years! He also paid for the extensive further engineering development work which resulted in the first Watt water pumping engine being successfully installed in a coal mine in 1776. The Soho works only made the crucial engine valve parts before 1796, the completed engines being made by recommended manufacturers. However, as Boulton and Watt also trained the installation engineers, they also maintained a high degree of product quality control, unlike the Newcomen engine. Their manufacturing operations were not particularly lucrative, especially given the initial development costs. However, given their patent monopoly, they made their real money (the so-called premium) by charging the user an annual fee equal to a third of the annual fuel savings obtained by the new compact Watt engines. Initially this was a good deal for both sides, especially in Cornwall where the Newcomen engine was completely superceded by 1783. For example, in 1779 a Cornish mine had used two Newcomen engines costing £5000 with a daily fuel cost of £14.7. The single replacement Watt engine cost £2500 and £6.9/day thus saving around £2000 a year thereafter. Nevertheless few mine owners relished paying out such large premiums till Watt's patent ran out in 1800, especially as the Cornish copper industry came under severe financial pressure due to the discovery of cheaper supplies in Wales. There was talk of getting the patent revoked and Boulton did adjust the premium downwards, devising the measure of "horse power" (i.e. the number of horses replaced by the engine) as a bargaining tool. Meanwhile, Boulton saw that the major application of Watt's engine was for powering rotative machinery and directed Watt's efforts in this direction, resulting in 4 further steam engine patents. By 1793 Watt engines were being used for a wide variety of applications e.g. wool and cotton mills, iron foundries etc which eventually brought in more business than mining.

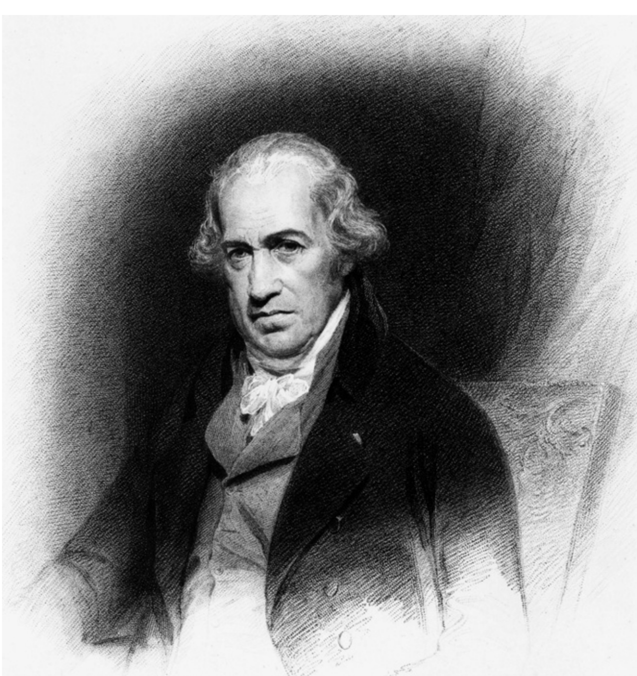

Fig. 2. James Watt.

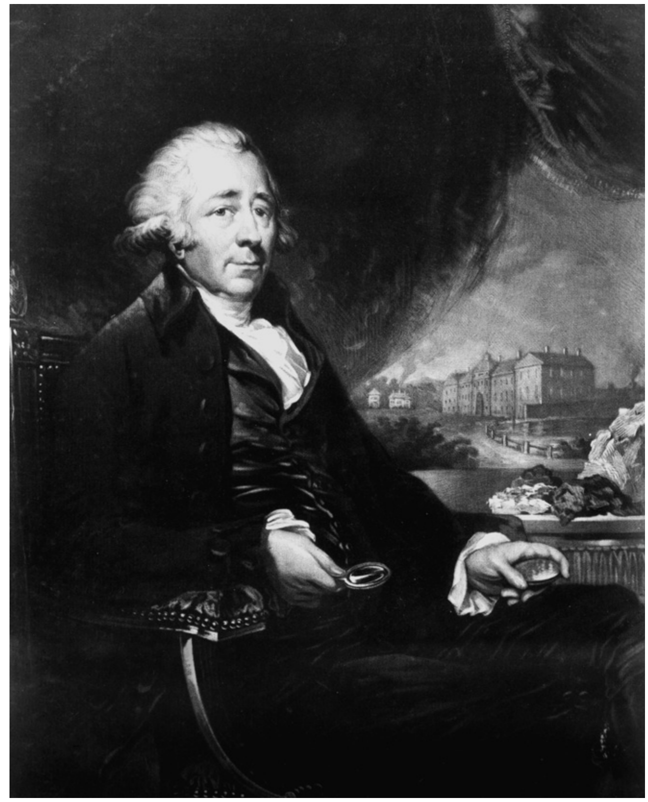

Fig. 3. Matthew Boulton.

6. Patent litigation

Short of revoking the patent an obvious solution was to design an engine falling outside its scope, a difficult task indeed as Watt's original patent had been drafted so broadly that it effectively covered all steam engines apart from the inefficient Newcomen engine. Nevertheless Cornwall had many talented engineers and Johnathan Carter Hornblower (1753–1815) patented a so-called "compound engine" in 1781. However, as initially it did not work well Watt did not sue. In his words:

> "One should not warn a man that we mean to break his head, lest he put on a helmet"

However, Hornblower persisted and installed eleven machines from 1782–1791. Eventually Watt threatened action and the owners paid royalties. Others made further attempts; in particular Edward Bull and Richard Trevithick (1771–1833) installed a so-called "inverted engine" in 1792. There then followed six years of expensive litigation through a succession of Courts in England's convoluted legal system. Watt's friend Erasmus Darwin (father of Charles Darwin of evolution fame) had warned him against relying on the law to protect his patents with the words (still apposite today):

> A lawsuit that pays well to the lawyers goes on like a snail creeping up a pole, which slips down again every 2 or 3 inches as he advances until he has beslimed the pole all over.

Fig. 4. Richard Trevithick.

Despite this advice they brought Bull to the Court of Common Pleas in 1793 and provided eight technical witnesses plus three to prove infringement whereas the defendants provided seven of their own. Thus most of the GBs leading steam engine experts were involved, hardly surprisingly as the main point at issue was whether Watt's specification was sufficiently described. The jury found in Watt's favour but the Judge ominously commented:

> I confess I have myself very great doubt whether this Specification is sufficient

As a result an injunction was granted against Bull but he and Trevithick went on making engines. One problem was in actually serving a writ on Trevithick in Cornwall. On one occasion Watt's bailiff was suspended on a rope over a deep mine shaft by a group of angry miners till he agreed to desist! A writ was only served when Trevithick unwisely made a trip to Birmingham. The Court reconsidered the sufficiency of Watt's patent without reaching a decision in June 1794, repeating the process in early 1795. In May 1795, the Court tried again; this time four judges wrote detailed decisions but, as they disagreed, no judgment was given. In June 1796 the defendants tried to remove the decision in the Court of Chancery but the Court upheld the injunction. Trevithick gave up his struggle in 1796 but Stephen Maberley bought a steam engine patent in the name of Isaac Mainwaring. It didn't work properly but Hornblower's brother made it work using Watt's ideas. Boulton and Watt obtained an injunction in the Court of Common Pleas so the defendants appealed to the Court of the Kings Bench who reconsidered the sufficiency of Watt's patent again in 1798 and 1799. However, this time all four judges ruled that Watt's patent was sufficient which, at long last, settled the matter. This enabled Boulton and Watt to collect over £30,000 in back royalties from infringers. Thus by 1800, when their original patent expired, they had received an unprecedented 31 year monopoly for the key steam engine technology. It was estimated that this was worth about £200,000 to them overall (around £20 million at 2007 prices).

7. Conclusions

This litigation set a clear precedent for the later working of the patent system; thereafter no industrialist could consider patents to be an expensive oddity, they were clearly an essential feature of innovation to be ignored at one's peril. Patents had come of age. Despite the expensive procedures, the number of GB patents continued to steadily rise. By the 1840s they averaged about 450/year and, after 1852, when procedures were simplified and cheapened, they increased to over 2000/year.

Acknowledgement

The author is grateful for the permission of the Science Museum, London, UK, to reproduce Figs. 1–5 here.

Annex 1. Postscript: The 200th anniversary of steam driven road and rail transport?

The long awaited expiry of Watt's main patent gave everyone else scope to pursue their own ideas. Prominent among these was Trevithick (see Fig. 4) whose interest in high pressure steam (so-called "strong steam" which Watt abhored for safety reasons) enabled the construction of relatively compact and powerful engines which could drive vehicles.

The first steam driven vehicle appears to have been constructed by Nicholas Joseph Cugnat in France in 1769 as a tractor for artillery but never seems to have got beyond the experimental stage. In England, William Murdoch had some successful trials in the 1780's and 90's but, when he prepared to file a patent, was threatened with legal action by Boulton and Watt. As they were also his employer he desisted, distinguishing himself later by producing gas from coal.

Trevithick's first steam driven road vehicle appeared on the Cornish roads in 1801 and he formed a partnership with his cousin Andrew Vivian to develop the engine. However, its poor steering mechanism led to a crash, Trevithick and his crew went to an Inn to repair their spirits (or drown their sorrows) while neglecting to put out the fire, and the result was a total write off. Nevertheless they obtained their patent in 1802, taking technical advice from leading scientific experts including Humphry Davy and Count Rumford. Directed to "A high pressure steam engine" it "applies engine to move a carriage" and also describes "an engine for crushing sugar". Clearly their patent was drafted with some care as it covered both static and dynamic applications for the engine. The following year a new steam carriage was built and successfully driven around London. It was a massive vehicle, with 8 inside passengers, and could travel at up to 8 mph on the flat though the steering and suspension were less than ideal (see Fig. 5).

Despite attracting much interest no commercial orders were received and Trevithick gave up on road vehicles to concentrate on static applications where business was booming. Nevertheless he experimented with a vehicle which could move on rails, these being already widely used by horse drawn vehicles in mining etc. This culminated in 1808 when an 8 ton engine, called the "Catch me who can", was run on a circular track in London at speeds on 12 mph and members of the public could pay for rides. The only technical problem was that the rails were too flimsy for the weight but the commercial problem was that there were again no orders. He sold his share in the patent and turned to other fields including steam ship propulsion and dredging, dry docks, screw propellors etc and spent much time in South America. Despite obtaining more patents than Watt he never made (or kept) any serious money.

Fig. 5. Picture of full scale working replica of Trevithick and Vivian's London carriage.

Trevithick was a brilliant engineer with potentially strong patents but, unlike Watt, never found a partner like Matthew Boulton with the commercial drive and strength of character to focus his attentions on successfully implementing a few ideas rather than dissipating his energies on a multiplicity of technically promising schemes which never achieved major commercial success. Had he done so we might now be celebrating the 200th anniversary of successful steam driven road and rail transport!

Annex 2. Patents

The GB patents relating to steam engines, and much other history of this subject as well, are extensively covered in the abridgements of GB patents published 1870, especially the Steam Engines Class. These are popularly known as the Bennet Woodcroft abridgement volumes.

A few pertinent examples are:

David Ramseye No 50 granted 21/1/1630
Thomas Savery No 356 granted 25/7/1698
James Watt's 5 engine patents Nos:
913 granted 05/01/1769
1306 granted 25/10/1781
1432 granted 28/04/1784
1321 granted 12/03/1782
1485 granted 14/06/1785
He also filed a patent for a document duplicating machine- No 1244 granted 14/02/1780
Matthew Boulton No 1757 granted 8/7/1790 A steam engine for coining and stamping presses
Jonathan Hornblower No 1298 granted 13/7/1781
Isaac Mainwaring 1792 granted 10/2/1791

Trevithick had 14 patents covering a wide range of subjects starting with:
Richard Trevithick and Andrew Vivian No 2599 granted 24/3/1802 and finishing with:
No 6308 granted 22/9/1832 relating to boilers

Reference

[1] Hewish J. Rex vs Arkwright, 1785: a judgement for patents as information. World Patent Inform 1986;8 (1):33–7.

Brian Spear is a Chartered Engineer and Fellow of the Institution of Electrical Engineers whose career was spent in the UK Patent Office. This included 22 years examining patents relating to computers, control systems and telecommunications. He has also spent 10 years on developing computer databases/searching, working in their commercial search arm—the Search and Advisory Service, and on IPR lecturing to a wide range of organisations. Since retiring he has completed an M.Sc. in the History of Science, Medicine and Technology at Imperial College London.